Bioconjugation between CdTe nanowires and Au nanoparticles: Fluorescence enhancement

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The interaction between semiconductor nanowires (NWs) and metallic nanocolloids were studied upon bioconjugation of two biomaterials: d-biotin and streptavidin. 5-fold intensity enhancement of luminescence and a blue shift of the emission peak were observed after conjugation with Au NPs. It can be interpreted in terms of the electromagnetic field enhancement effect in the presence of metallic NPs and demonstrated that the strong luminescence enhancement should be treated as a collective response of Au-NPs.

Keywords: nanowires, nanoparticles bioconjugates, luminescence enhancement, superstructures, collective effects.

1. INTRODUCTION

Complexes of CdTe NWs with Au NPs have been prepared by taking advantage of biotin-streptavidin affinity pair in this paper. A 5-fold enhancement of fluorescence intensity of CdTe-NWs conjugated with Au-NPs is experimentally demonstrated and theoretically explained. These studies suggested that the maximum enhancement effect can be achieved when the interactions of plasmons in NPs layer on NW have a collective character.

2. EXPERIMENTAL

All chemicals used in this experiment: e.g., $Cd(ClO_4)_2 \cdot H_2O$, L-cysteine, Al_2Te_3, NaOH, Streptavidin (SA) and d-biotin (B) were purchased from Aldrich and used without further purification. 1-ethyl-3-(3-dimethlamino propyl) carbodiimide hydrochloride (EDC), and N-hydroxy-sulfosuccinimide (NHS) were purchased from Aldrich and Merck for bioconjugation, respectively. Au NPs, CdTe NPs and NWs were prepared as mentioned elsewhere in detail.[1-3]

The average diameter of CdTe NP was measured as 3.7 nm within 10% standard deviation and CdTe NWs have diameter of 5.8 ± 1.1 nm, average length of 1027 ± 92 nm (the aspect ratio of 179) and photoluminescence at 670 nm. The diameter of NPs was measured as 3.7 nm using transmission electron microscopy (JEOL 2010F). EDC/sulfo-NHS cross linking procedure was utilized to link affinity bioligands on Au NPs

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and CdTe NWs.[4] The solution was stored at 4°C and showed strong fluorescence for 2 weeks.

The luminescence spectra of NP-NW dispersions were measured with a Fluoromax-3 spectrofluorometer (Jobin Yvon/SPEX Horiba) every 2 - 10 min for up to 2 hrs. The fluorescence lifetimes (τ) were measured with a Fluorolog Tau-3 (Jobin Yvon/SPEX Horiba).

3. RESULTS

Figure 1A presents TEM image of Au NP conjugated CdTe NWs. When Au NPs are conjugated to NWs, they can be distinguished by the specific crystal lattice fringes of Au; i.e., The lattice parameter (*d* spacing) of the crystalline CdTe NWs was 0.398 ± 0.01nm, typical for hkl (100) hexagonal wurtzite CdTe structures while The Au NPs had a lattice spacing of 0.23 ± 0.008 nm.[5]

When NP-SA are added to NW-B, a distinct change in luminescence intensity of CdTe nanocolloids can be seen (Figure 1B). The peak luminescence intensity was enhanced 5 times while the maximum wavelength of each spectrum gradually shifted toward high energies (blue shift).

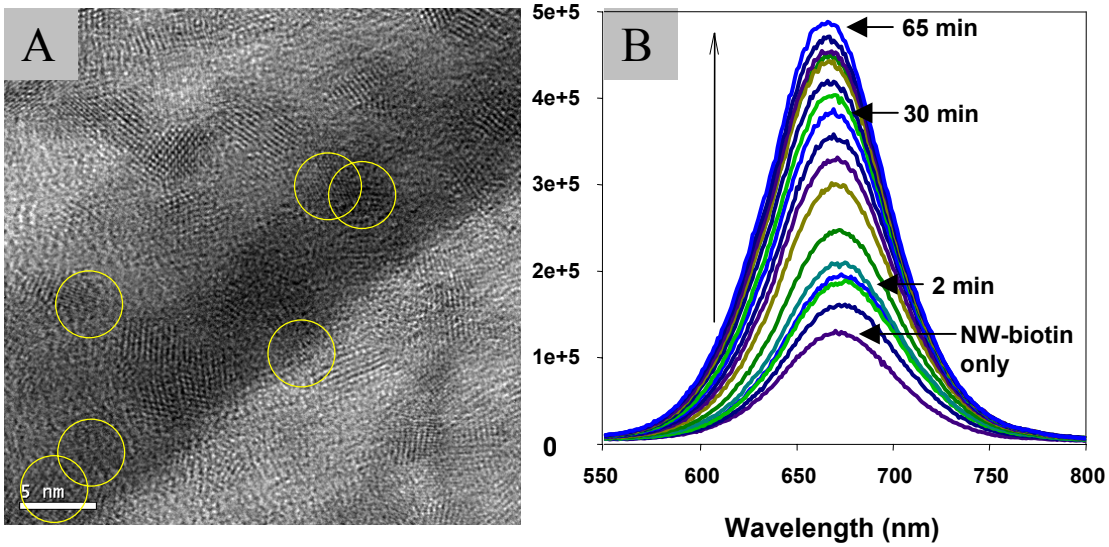

Figure 1: (A) TEM images (500k×) of Au bioconjugated CdTe NW in solution. Yellow circles indicate the areas of metallic Au after bioconjugation. (B) NW-B with SA-Au monitored for 65 min. Excitation wavelength is 420 nm.

4. DISCUSSION

The interactions between plasmons and excitons via electric fields can lead to luminescence enhancement of CdTe NW. Since plasmon excitations result in strong electric fields in the vicinity of Au NPs, the optical properties of NW become strongly

changed. Exciton-plasmon interactions can explain the experimental observations in Figures 1B regarding the enhancement and blue shift of the CdTe NWs. The lifetime of excitons becomes shorter with Au-NPs and consequently the diffusion length of excitons in a NW decreases. Because the NW is not entirely homogeneous and has some variations in the structure and diameter along the NW length, short-lived excitons do not have enough time to diffuse into the regions of NW with the lowest energies and therefore create photons in the regions of NW with relatively large band gap. Consequently, the population of the comparatively narrow band-gap regions decreases and the emission is observed from the places close to the point of their absorption.[6]

5. CONCLUSION

A new type of NP-NW superstructures with SA-B bioconjugation was utilized to study unique optical effects in nanomaterials, which results in stemming from exciton-plasmon interactions. It was also suggested that the electromagnetic enhancement from Au-NPs on or near CdTe NWs result in the blue shift of CdTe NW light emission and substantial shortening of the luminescence life-time.

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